Is Nonlinear Analysis Becoming a Standard Tool for Design and Assessment of Reinforced Concrete Structures?

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Abstract

The nonlinear finite element method has become a standard tool serving engineers during the designing of reinforced concrete bridges. Compared to a linear solution, the main advantage is that it can provide a better insight into the realistic material response including crack formation and subsequent redistribution of internal forces. In this paper, the key aspects related to the application in engineering practice are summarised, including the theory behind the nonlinear material model and the explanation of the solution method. Based on validation against experimental data, the accuracy of a given nonlinear tool can be quantified and translated into a model partial safety factor. This factor then serves as a parameter in the evaluation of the design structural resistance. Finally, we show an example of an assessment of a post-tensioned reinforced concrete bridge, where strengthening provisions were adopted to reinforce a critical region with crack formation.

Keywords: finite element analysis, reinforced concrete structures, nonlinear simulation, damage mechanics, smeared crack models, reliability analysis.

1 Introduction

Application of the nonlinear finite element method (FEM) during the designing of reinforced concrete structures offers engineers an important perspective into the realistic behavior of the structure. Advanced material models can evaluate the crushing of concrete when subjected to high compressive stress as well as cracking when the tensile strength is exceeded. Furthermore, for the reinforcement material, yielding and even rupturing can be simulated. By these means, a complex assessment of the structural performance is feasible. Compare to traditional design approaches based on the classic beam theory, nonlinear FEM can accurately consider complex geometries, stress states, and loading histories. This allows assessment of the structural integrity for static, dynamic, and environmental loads as well as consideration of the long-term rheological phenomena such as concrete creep.

The applicability of the nonlinear FEM simulation has been rigorously shown in literature and is often checked in benchmark competitions. Based on these findings, modeling uncertainties can be quantified. To utilize nonlinear analysis in engineering practice, proper guidelines need to be available. Currently, these provisions are given in the *fib* Model Code 2010 [1] and will be introduced in the new generation of Eurocodes. These standards incorporate the model uncertainty, which should be specific to each material model and software package.

This paper is structured to first give a brief theoretical overview of the non-linear FEM, demonstrate its applicability using examples from benchmark competitions, and finally present a code-based framework for engineering application.

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